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Morecroft, John D W
Management Science (pre-1986); Jul 1985; 31, 7; ABI/INFORM Collection
pg. 900

MANAGEMENT SCIENCE
Vol. 31, No. 7 July 1985
Printed in U.S.A

RATIONALITY IN THE ANALYSIS OF BEHAVIORAL SIMULATION MODELS*

JOHN D. W. MORECROFT
Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

An important task in the analysis of a behavioral simulation model is to explain clearly how the model's organizational assumptions lead to its simulated behavior. All too often, model-based arguments involve an uncomfortable "leap of logic" between equations and consequences. This paper proposes two methods of analysis, premise description and partial model testing, which provide stepping stones between model equations and their simulated consequences. Premise description examines the bounded rationality of policies or decision functions in the model, pointing out the process and cognitive limitations assumed in decisionmaking. Partial model tests expose the intended rationality of small combinations of policies, showing that policies produce "sensible" actions with respect to their premises. The application of those methods is illustrated with a simulation model of a sales organization in which sales-force productivity is prone to decline. The behavior of productivity is traced to dysfunctional interactions between objectives, overtime, and salesforce motivation.
(BEHAVIORAL SIMULATION MODELS; SYSTEM DYNAMICS; BOUNDED RATIONALITY; SIMULATION ANALYSIS; SALESFORCE AND PRODUCTIVITY)

Introduction

Suppose we learn that a magazine publisher goes out of business and that the circumstances leading up to the collapse are record losses and, at the same time, record revenues and circulation—circumstances that have occurred in the past.[1] Then suppose we are faced with the problem of explaining this outcome, of developing a theory that will account for the choices and actions that could lead a successful enterprise into demise. It is clearly unreasonable to assume that the business failure occurred because strategy was deliberately designed to cause major losses. A much more satisfying explanation will result if we assume that the separate policies comprising the strategy were intendedly rational (in other words, intended to produce a desirable outcome), but, when linked in a commercial setting, they produced an unexpected and undesirable outcome.

The idea that dysfunctional behavior can arise from well-intentioned actions is not new. It is central to the systems view of organizations (Churchman 1969) and pervades descriptive-process interpretations of business policy (Hall 1984) and even government policy (Allison 1971). Despite the prevalence of the idea, it has not been applied to the analysis and testing of behavioral simulation models, particularly in the field of system dynamics. One does not find simulation analyses where the behavior of one part of a model is shown to be well-intentioned, then another part, then another, and so on; yet the behavior of the whole model is revealed as dysfunctional. Usually, dysfunctional behavior is presented as a fait accompli and claimed to result from the micro assumptions embodied in individual equations. But the logical step from micro

* Accepted by Arie Y. Lewin; received June 16, 1983. This paper has been with the author 5 months for 2 revisions.

[1] An account of the failure of the *Saturday Evening Post* is provided in Harvard Business School Case Study 9-373-009 (1972). A fascinating model-based theory of the failure is provided in Hall (1976).

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assumptions to whole model behavior is large and nonintuitive and can often undermine confidence in model-based explanations of business and social problems.[2]

This paper proposes two methods of analysis, premise description and partial model testing, which provide stepping stones between model equations and their simulated consequences. Premise description examines the bounded rationality of policies or decision functions in the model, pointing out the process and cognitive limitations assumed in decisionmaking. Partial model tests expose the intended rationality of small combinations of policies, showing that policies produce "sensible" actions with respect to their premises. The contrast of partial and whole model simulations results in a clearer understanding of the causes and persistence of dysfunctional behavior.

The application of these methods is illustrated with a simulation model of a sales organization in which sales-force productivity is prone to decline. The model was derived from a large project model used to examine the marketing strategy of a datacommunications firm. The behavior of productivity is traced to dysfunctional interactions between sales objectives, overtime, and sales-force motivation.

Bounded Rationality and Organizational Process

In order to apply the methods of premise description and partial model testing, it is necessary to review the concept of bounded rationality and the requirements it makes of organizational decisionmaking. According to Simon (1957), bounded rationality is a property of decisionmaking that reflects people's cognitive limitations. Individuals faced with complex choices are unable to make objectively rational decisions because (1) they cannot generate all the feasible alternative courses of action, (2) they cannot collect and process all the information that would permit them to predict the consequences of choosing a given alternative, and (3) they cannot value anticipated consequences accurately and select among them.

Problems of choice in organizations are particularly complex due to the wide range of feasible courses of action available and the large amount of information required to monitor and coordinate actions. That reasonably good decisions are made at all is due to the specialization and narrowing of decisionmaking responsibilities that occur in organizations. As Simon (1979, p. 501) has pointed out, organizations are structured to "transform intractable decision problems into tractable ones." Individuals in organizations exhibit only bounded rationality—they make rational decisions under conditions of choice that are simplified.[3] But this simplification is a two-edged sword. It allows seemingly rational choices to be made by many decentralized decisionmakers but does not guarantee that their choices are consistent and mutually supportive.

Below there is a review of the most common organizational processes for simplifying decisionmaking.

Factoring. Factoring simplifies decisionmaking by producing a network of specialized decision functions (Allison 1971, Cyert and March 1963). In such a network, information is distributed among the decision nodes of the system. Each decisionmaker receives only part of the available information flow, an amount sufficiently

[2]For a thoughtful discussion of problems of computer simulation and theory building, see Frijda (1967). The paper discusses the modeling of psychological processes but makes several interesting methodological points about the strengths and weaknesses of simulation for theory creation. Bell and Senge (1980), Forrester and Senge (1980), Mass and Senge (1978), and Naylor and Finger (1967) discuss some thought-provoking issues in the validation of model-based theories.

[3]Simon's *Administrative Behavior* (1976) describes the simplification of decisionmaking in terms of a psychological environment "that will adapt [the organization members'] decisions to organizational objectives, and will provide them with the information needed to make these decisions correctly."

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small to allow timely processing and action. But no individual has the whole picture. Like the blind men and the elephant, each decisionmaker has a unique but limited perspective on the organization depending on his information sources.

Goals and Incentives. Goals and incentives can simplify decisionmaking by focusing managerial attention on specific measures of performance. For example, some production departments are evaluated on their ability to meet quarterly shipping goals. These goals often dominate production scheduling decisions to the exclusion of more complex economic criteria. As the quarter draws to a close, frantic changes are made to the production schedule to ensure that the shipping goal is met—regardless of the economic consequences. While such decisionmaking is often labeled shortsighted, it is important to realize that it is simple. The production schedule is based on the sole criterion that the shipping goal is met and does not require fine tuning of overtime and inventory carrying costs. In terms of information flows (and, therefore, model structure), goals determine what information is of central importance in making decisions (e.g., performance against the shipping goal) and what information can be safely ignored (e.g., short-run cost of production).

Authority and Culture. Authority and corporate culture also simplify decisionmaking, though often intangibly. They serve to transmit the basic values and traditions of the organization to all its members. Authority and culture permeate thinking at the decision nodes of the enterprise, altering the premises of decisionmaking and often introducing bias and distortion into the interpretation of information.

For example, in an interesting case modeled by Forrester (1968) the president of a company with a fast growing new product line insisted on maintaining strict personal control over the approval of all capital expenditures. As a result, the company's decision process for capital-equipment ordering was biased. Considerable demand pressure in the form of high order backlogs had to accumulate to justify expansion. The model that incorporated this conservative facet of corporate culture showed that the bias in capital-equipment ordering could cause sales to stagnate in a market with large untapped sales potential.

Routine. Organizations evolve routines, which provide yet another way of simplifying decisionmaking (Allison 1971, p. 83, Nelson and Winter 1982, pp. 96–136). Routines call for small amounts of information from predetermined sources to be processed with simple rules of thumb. For example, in the magazine publishing industry a prevalent routine is to link the number of pages to be printed in a given issue to the number of advertising pages sold (Hall 1976, p. 195). More advertising pages result in a thicker magazine. This procedure can work well, but its blind application has in the past contributed to financial loss as the costs of magazine production and distribution outstripped revenues.

Basic Cognitive Processes. When the conditions surrounding decisionmaking have been simplified by factoring, by goal formation and incentives, authority, culture, and routine, there still remain limitations on rationality imposed by cognitive processes.[4] People take time to collect and transmit information. They take still more time to absorb information, process it, and arrive at a judgment. There are limits to the amount of information they can manipulate and retain. These cognitive processes can introduce delay, distortion, and bias into information channels, which behavioral models should capture and the modeler should explain.

Premise Description and Bounded Rationality

Premise description highlights the organizational processes and cognitive limitations that bound the rational adjustment of each decision function. Although this style of

[4] For a detailed account of cognitive limitations, see Hogarth (1980).

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description was used in the early simulation models of Cyert and March (1963), it has not been used in describing the more widespread behavioral models of system dynamics. The advantage of premise description over more conventional methods of model description (such as equation-by-equation description as in, say, Forrester 1961, pp. 215–251) is that the behavioral and cognitive assumptions of the model are made much more explicit.

The modeler starts with a diagram of the model system showing the network of interlinked decision functions. He then describes the equations of each decision function, drawing attention to the way factoring and local goals simplify rational choice, how authority and culture influence the content and interpretation of information streams, and how routine and cognitive limitations influence the collection, processing, and transmission of information.[5] At the back of his mind the modeler has the notion of objective rationality as a yardstick. This yardstick raises questions of why some information is available in a decision function and other is not, why delay and distortion occur in the transmission and interpretation of information, and why bias is present. The answers to these questions naturally point to empirically observed organizational processes that stem from bounded rationality.

Such a model description alerts the reader to the deficiencies present in the information network and signals the possibility of problem behavior in the system as a whole. The decision functions of the model are seen to be intendedly rational within the bounds set by common organizational practice, yet far removed from the demanding standards set by objective rationality.

Partial Model Tests of Intended Rationality

Partial model testing has long been used in simulation modeling to debug subsystem models prior to whole model simulations. Here we suggest that partial tests have a much more important role to play in model analysis. They should be used to expose the intended rationality of organizational decisionmaking.

A single assumption justifies the new and important role of partial model tests. It is that decisionmaking is rational within the context of the premises supplied to the decisionmaker and the limits of his computing capacity.[6] This assumption enables one to decompose a complex simulation model into pieces and to *expect* simulation runs of the pieces to reveal intuitively clear, plausible behavior. The partial tests should show that local decisions are well adapted to achieving local goals. The assumption of intended rationality does *not* imply that the behavior of the *whole* system is well adapted to the many goals of the enterprise. Dysfunctional behavior is quite possible but is a systemic problem resulting from the coupling of decision functions—in other words, a flaw in the structure and design of the organization as a whole.

The analysis begins with a causal-loop diagram (Richardson and Pugh 1981, pp. 25–30) that shows the feedback loops resulting from organizational, cognitive, and physical assumptions of the model's equations. The causal-loop diagram is then used to design a sequence of simulation experiments to explore the behavior of pieces of the total feedback structure.[7] The tests show how one (or perhaps a few) decision functions

[5] This kind of formulation description was used in Morecroft (1983), though not as an explicit descriptive aid.

[6] Decisionmaking that is rational given its premises is intendedly rational with respect to its environment. Simon (1976, p. xxviii) has made the following interesting assertion on the assumption of intended rationality and its relationship to theory creation:

> It is precisely in the realm where human behavior is intendedly rational . . . that there is room for a genuine theory of organization and administration.

[7] For another example of partial model testing used to examine rationality, see Morecroft (1983).

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work when the premises of rational adjustment for the functions are not seriously violated. Partial tests are then compared with whole model tests to reveal the causes of behavior (particularly dysfunctional behavior) in the complete system.

The great strength of partial model testing is most apparent when the whole model (or some configuration of loops) exhibits counterintuitive and highly ineffective behavior.[8] The surprising behavior of the whole model can be traced to the interaction of many intendedly rational parts. In other words, by coupling many decision functions, the premises or conditions for rational adjustment of individual functions are violated. In these situations a system of decision processes is integrated in such a way that the rationality of the parts fails to be a close approximation to the objective rationality required for success of the total system. The contrast of partial and whole model tests provides a useful explanatory tool for behavior analysis.

A Behavioral Model of a Sales Organization

In this section a simple model of a sales organization is described and analyzed using the methods of premise description and partial model testing. The simple model is based on a much larger model developed to examine marketing strategy for a company selling advanced datacommunications equipment. The larger model contains more than 100 active equations that describe some 20 interlinked decision functions, covering customer purchasing, price perceptions, salesforce time allocation, quitting, overtime, motivation, and sales objective setting. The structure of the larger model, in terms of factored decision nodes, information flows, heuristics, routines, biases and so forth, was derived in interviews and discussions with the sales force, marketing staff, and company executives, as described by Morecroft (1984).

The simple model contains just 14 equations and focuses attention on the decision functions for overtime and objective setting, and the behavioral function for salesforce motivation. The structure and parameterization of these functions are virtually unchanged from the larger model. The rationality of the simple model is therefore representative of the larger, empirically derived model. Moreover, simulations of the small model show the same declines in salesforce productivity as exhibited by the larger model for reasons that were found plausible and persuasive by the company's managers and executives.

Model Overview—Factored Decisionmaking

Figure 1 shows six policy functions in the simple model for sales, sales objective, performance, overtime, motivation, and sales effort. Policy functions are represented by circles and are connected by information flows shown as dotted lines.[9] On the right side of the figure, sales are generated by sales effort measured as the total number of hours the sales force spends with customers. In this market, salesforce persuasion is an important factor in the customers' ordering decision. More salesforce hours generate more sales according to the average time required per sale (shown as a constant in the figure). Moving clockwise around Figure 1, the next policy function is the sales objective. The sales objective is a projection of trends in past sales volume and so receives a flow of information from the sales function. The performance of the sales force is shown as another policy function which compares information on current sales with the sales objective. Salesmen use performance to decide their overtime hours, more if performance is poor and fewer if it is good. Overtime then determines sales effort together with the size of the sales force (assumed constant in the simple model)

[8] See Mass (1981) for further discussion of the process of diagnosing surprise model behavior.

[9] For a discussion of policy structure diagrams and their relationship to other diagramming methods in system dynamics, see Morecroft (1982).

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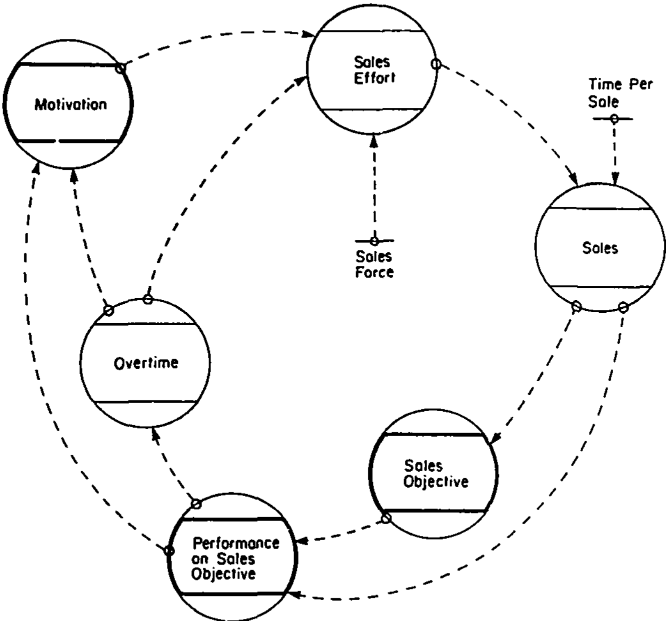

FIGURE 1. Policy Structure of a Simple Sales Organization.

and its motivation. Motivation is a purely behavioral function (rather than a conscious decision function) that represents the response of salesmen to varying conditions of overtime and performance.

To summarize, the major decisionmaking nodes are the setting of the sales objective, which is the responsibility of market planning managers; assessment of the sales performance, which is the concern of field sales managers and their salesmen; and finally overtime, which is the personal responsibility of individual salesmen.

Premise Description of Decision Functions

Premise description draws attention to the sources, uses, and interpretation of information in the sales objective and overtime functions.[10] (A documented listing of the equations of the complete model is available from the author.)

(a) Sales Objective

$$MSO_t = MSC_t^*(1 + MASC), \tag{1}$$

$$MASC = 0.05 \text{ Dimensionless}, \tag{1.1}$$

$$MSC_t = MSC_{t-1} + (1/TESC)(MS_{t-1} - MSC_{t-1}), \tag{2}$$

$$MSC_0 = MS_0, \tag{2.1}$$

$$TESC = 12 \text{ Months}, \qquad \text{where} \tag{2.2}$$

[10]The model was written in the DYNAMO simulation language (Pugh 1976). DYNAMO equations are similar to discrete difference equations with one major distinction: they allow the time units used for describing the model's decisionmaking to be independent of the time units used for computation. Only when the time units of description and computation are equal and set at unity are the DYNAMO and discrete difference equations strictly identical. The reader should therefore treat the difference equation format presented in the text as an approximation to the DYNAMO format and realize that in all simulation runs the time unit of computation is one week, but the time unit of description is one month.

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MSO—Monthly Sales Objective (Units Per Month),
MSC—Monthly Sales Commitment (Units Per Month),
MASC—Margin for Achievement of Sales Commitment (Dimensionless),
MS—Monthly Sales (Units Per Month),
TESC—Time to Establish Sales Commitment (Units Per Month).

The sales objective is a particularly interesting example of bounded rationality that illustrates the role of authority, organizational routine, and cognitive limitations in forming the premises of decision.

Equation (1) states that the monthly sales objective *MSO* is based on a monthly sales commitment *MSC* inflated by a fixed 5% margin *MASC*. The formulation captures a political goal formation process. Market managers commit to higher-level executives to sell a specific volume of products. Their performance is judged on their ability to fulfill this commitment. So, when setting objectives, they deliberately inflate the sales commitment, in this case by 5%. The margin provides managers with security and, at the same time, pressures the sales force to improve on its past sales performance. It is a remarkably simple device by which executive pressure for cost-effective performance can be transmitted through middle-level managers to spur the efforts of salesmen.

Equation (2) states that the monthly sales commitment *MSC* is an exponential smoothing (Forrester 1961, pp. 406–411) of past monthly sales *MS* with a time constant *TESC* of twelve months. At the heart of the sales-commitment process is the routine of committing to sell in the future the same amount as was sold in the recent past. It is a routine that demands little detailed information—certainly much less than would be required by sophisticated market forecasts and surveys.

(b) Overtime

$$MOT_t = f_1(PSO_t) \qquad \text{where} \tag{3}$$

MOT—Multiplier from Overtime (Dimensionless),
PSO—Performance on Sales Objective (Dimensionless),
f_1—Nonlinear Decreasing Function of *PSO*.

Equation (3) states that overtime is a nonlinear function f_1 of performance on the sales objective *PSO*. Provided salesmen are meeting or exceeding the sales objective ($PSO > 1$), they work the standard 130 hours per month, and the multiplier from overtime *MOT* remains neutral at 1. As performance falls below the objective ($PSO < 1$), salesmen feel increasing pressure to work harder, both to look good on the job and to avoid loss of income from sales bonuses. For example, when sales are running at 90% of the objective ($PSO = 0.9$), salesmen are assumed to work 25% overtime ($MOT = 1.25$). At 80% performance they are assumed to work 40% overtime, the peak attainable.

The most notable cognitive feature of the decision function for overtime is its simplicity. Salesmen take performance on the sales objective as the sole premise for their overtime decision. They are not trying to maximize personal or corporate income, which would require a sophisticated, intertemporal computation of sales, performance, compensation, and motivation.

(c) Performance on Sales Objective

$$PSO_t = PSO_{t-1} + (1/TPSO)((MS_{t-1}/MSO_{t-1}) - PSO_{t-1}), \tag{4}$$

$$PSO_0 = IPSO, \tag{4.1}$$

$$IPSO = 1/(1 + MASC), \tag{4.2}$$

$$TPSO = 3 \text{ Months}, \qquad \text{where} \tag{4.3}$$

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PSO—Performance on Sales Objective (Dimensionless),
MS—Monthly Sales (Units Per Month),
MSO—Monthly Sales Objective (Units Per Month),
IPSO—Initial Performance on Sales Objective (Dimensionless),
MASC—Margin for Achievement of Sales Commitment,
TPSO—Time for Performance on Sales Objective (Months).

Performance on the sales objective *PSO* is formulated in equation (4) as an exponential smoothing of current performance with a time constant *TPSO* of 3 months. Here, current performance is the ratio of monthly sales *MS* to the monthly sales objective *MSO*. The formulation captures a natural judgmental smoothing process. A drop in monthly sales must be sustained for several months to persuade a salesman he is missing target and should take corrective action.

Description of the Behavioral Motivation Functions

This section describes the model's nonlinear motivation functions that relate salesmen's productivity to overtime and performance against sales objective. Unlike the earlier functions, which modeled conscious decisionmaking processes, these functions model purely behavioral assumptions about salesmen.

$$EMSE_t = f_2(M_t), \tag{5}$$

$$M_t = M_{t-1} + (1/TEM)(MI_{t-1} - M_{t-1}), \tag{6}$$

$$M_0 = IMI, \tag{6.1}$$

$$TEM = 3 \text{ Months}, \tag{6.2}$$

$$MI_t = (MIO_t^* MIP_t)^* SMI + (1 - SMI)^* IMI, \tag{7}$$

$$SMI = 0, \tag{7.1}$$

$$IMI = MIO_0^* MIP_0, \tag{7.2}$$

$$MIO_t = f_3(MOT_t), \tag{8}$$

$$MIP_t = f_4(PSO_t), \qquad \text{where} \tag{9}$$

EMSE—Effect of Motivation on Sales Effort (Dimensionless),
f_2—Nonlinear Increasing Function of Motivation,
M—Motivation (Dimensionless),
TEM—Time to Establish Motivation (Months),
MI—Motivation Index (Dimensionless),
SMI—Switch for Motivation Index (Dimensionless),
IMI—Initial Motivation Index (Dimensionless),
MIO—Motivation Index From Overtime (Dimensionless),
f_3—Nonlinear Decreasing Function of *MOT*,
MIP—Motivation Index From Performance (Dimensionless),
f_4—Nonlinear Increasing Function of *PSO*.

Equation (5) asserts that low motivation will reduce sales effort. Motivation is defined on a dimensionless scale from 0 to 1. Figure 2 shows the shape of the behavioral relationship. When motivation is high (around 1), it has little or no depressing effect on sales effort. As motivation falls below 0.8, it has an increasingly depressing effect on sales effort, reducing it by fully 35% when motivation reaches a value of 0.4. It is assumed that no matter how low motivation falls it will not depress sales effort by more than 60%.

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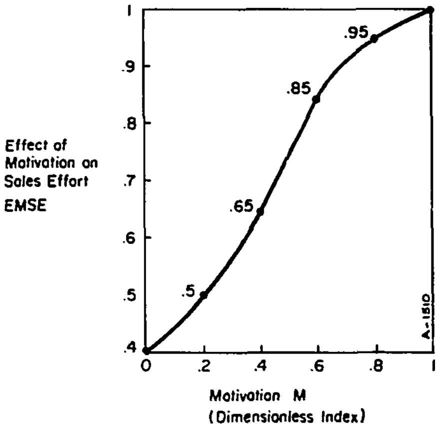

FIGURE 2. Effect of Motivation on Sales Effort.

Equations (6) through (9) state that motivation depends on working conditions. Conditions of high overtime or poor sales performance can both lead to low motivation. But it takes time to become demoralized. Equation (6) states that motivation M lags three months behind the motivation index MI, which is the index of current working conditions. In other words, an increase in overtime starting today will, on the average, result in lower motivation three months later. Conversely, a demotivated salesforce takes time to return to full productivity, even when working conditions become favorable.

In equations (7), (8), and (9) the motivation index MI is defined as the product of nonlinear functions (f_3 and f_4) of overtime MOT and performance on sales objective PSO. The shapes of the functions are shown in Figure 3. When overtime is moderate and performance is close to objective, the index is nearly 1, meaning that motivation is high. But conditions of high overtime *and* poor performance (which are apt to occur

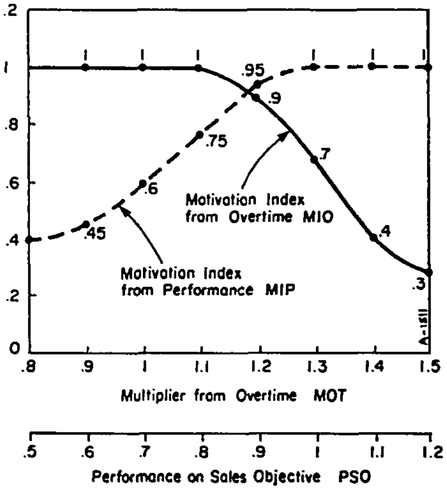

FIGURE 3. Determinants of the Motivation Index.

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simultaneously) bring about a precipitous drop in the motivation index. For example, if salesmen are working 30% overtime ($MOT = 1.3$) and their performance is 20% below objective ($PSO = 0.8$) then the motivation index assumes a value of $f_3(1.3) * f_4(0.8) = 0.7 * 0.75 = 0.525$, leading to a 25% drop in sales effort. The functions f_3 and f_4 do not have to fall far below 1 before their product $f_3 * f_4$ becomes small.

The formulation for motivation is not intended to model the complete behavioral response of salesmen to changing working conditions. For example, poor performance and high overtime may lead some salesmen to quit. Alternatively, poor performance may lead some salesmen to reduce their overtime hours rather than increase them, reflecting apathetic behavior. Neither of these possibilities is modeled (although quitting was modeled explicitly in the larger project model). In Mohr's terms (1982) the formulation for motivation is a ceteris quietis model of salesforce behavior, in which the excluded behaviors are assumed dormant. The resulting model is "optimistic" in the sense that productivity of the sales force is higher than it would be if factors such as quitting or apathy were included. Nevertheless, as later simulation experiments show, this optimistic bias in the model still results in dysfunctional behavior of the sales organization.

First Partial Model Test—Intended Rationality of Salesman Overtime Adjustment

Figure 4 shows four interlocking feedback loops that summarize the connections between the model's policy functions. The loops are used to design partial model tests of intended rationality. The first partial model test examines the behavior of loop 1 in isolation, showing how overtime adjusts to a decline in sales independently of changes in objectives or motivation. To conduct the test the model was disturbed from equilibrium by a 50% step increase in time per sale (from 60 to 90 hours per unit)[11]

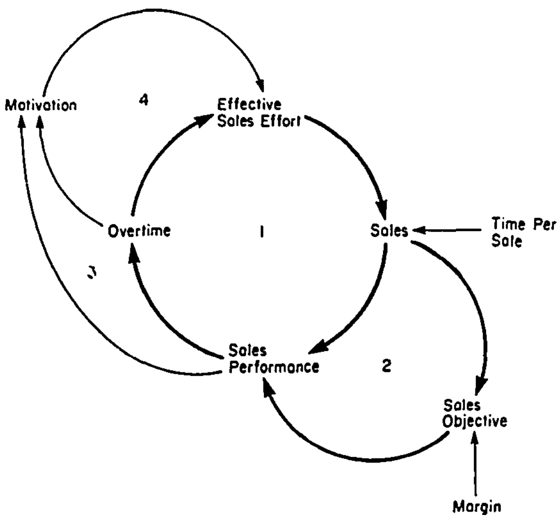

FIGURE 4. Feedback Structure of the Sales Model

[11] A 50% increase in the time required to sell the product is a significant tightening of the market, but quite plausible. For example, in the full-scale project model (Morecroft 1984) the market was being converted from old to new technology. The time to sell product rose rapidly when sales had been made to all the easy-to-convince customers, leaving only the die-hards in the old technology. Precisely when such a transition would occur was very difficult to predict.

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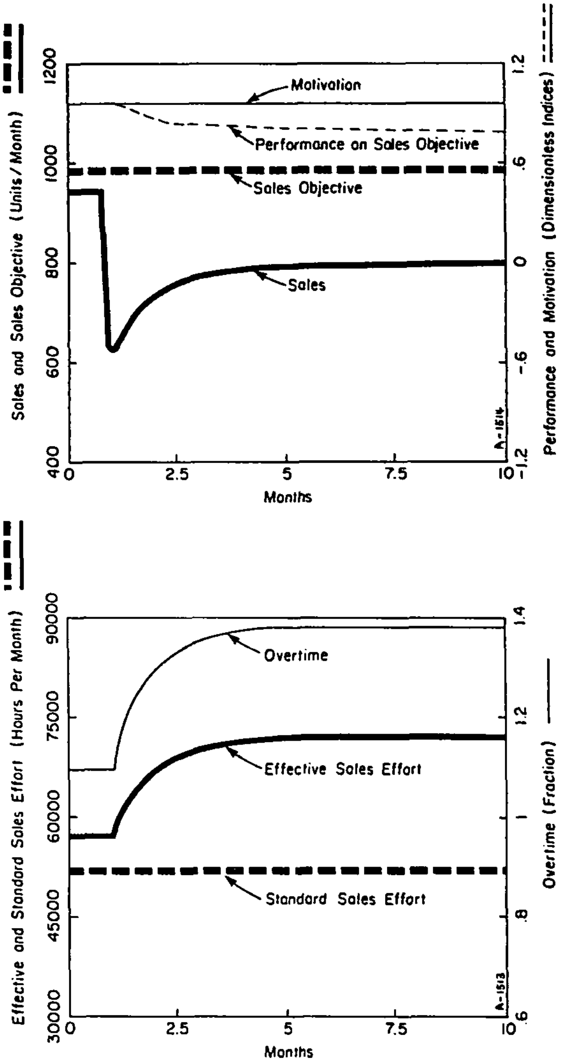

FIGURE 5. Salesman Overtime Adjustment—Loop 1 in Isolation.

while holding the sales objective fixed and neutralizing the motivation function (by setting the motivation index to 1).

The simplicity of the test makes the simulated behavior straightforward to interpret. Figure 5 shows that in month 1 sales fall by 1/3 in response to the 50% increase in time per sale. The resulting discrepancy between monthly sales and the objective causes salesmen to increase overtime from 10% (of the normal 130 hours per month) to a final value of 40%. More overtime results in greater sales effort, hence more sales. Most of the adjustment is complete in the first two months of the run. The system then settles into a "stressed equilibrium" in which salesmen are working long hours under pressure from an unyielding sales objective.

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What do we learn from the partial model test? First, we gain confidence that the model's assumptions produce intuitively correct outcomes. A reduction in sales does indeed elicit more effort from the sales force, as expected. Second, we see that the simple decision rules governing overtime are intendedly rational—poor performance leads to more overtime that improves performance. We should remember that exactly the same rationale is at work in the more complex whole model simulations.

Second Partial Model Test—Intended Rationality of Objective Setting

The second partial model test examines the behavior of loop 2 in isolation, showing how the sales objective adjusts to a decrease in sales, independently of changes in motivation or overtime.[12] To conduct the test the model was again disturbed from equilibrium by a 50% step increase in time per sale, while neutralizing the motivation function and holding overtime fixed at 10%. The results are shown in Figure 6. (Note that the time scale in this run has increased to 50 months from 10 months in the previous run.)

Monthly sales fall by 1/3 in month 4. The sales objective falls as market managers learn of the tighter market conditions and renegotiate their sales commitment with executives. But the fall is gradual. It takes time to be convinced that the decline in sales is permanent and not simply the result of unusual, but temporary, market conditions or reduced effort by salesmen. The market manager must have a convincing story to tell executives in order to negotiate a reduction in his sales commitment without loss of face. Routine and authority therefore result in considerable inertia in the sales objective. Nevertheless, the objective does respond in a rational though cautious way. Twelve months after the drop in sales, the objective is already adjusted 60% toward its new equilibrium value.

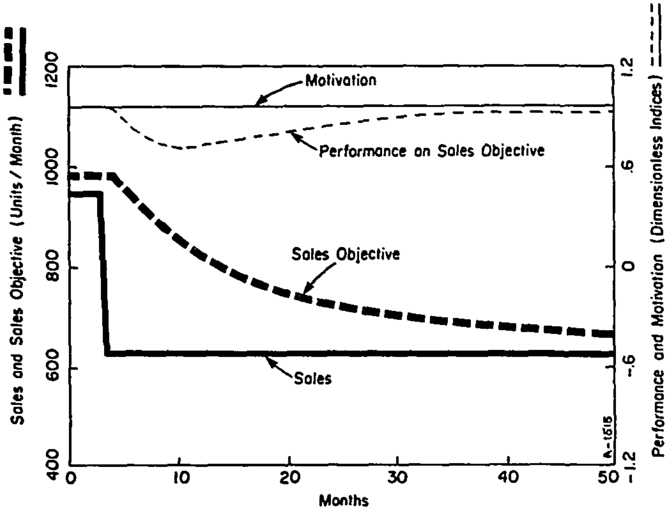

FIGURE 6. Adjustment of Sales Objective—Loop 2 in Isolation.

[12] Strictly speaking, when overtime is held constant (as it is in the second partial model test), loop 2 is not a closed feedback loop. The focus of the second partial model test is really the behavior of the link in loop 2 from sales to the sales objective.

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Bounded Rationality and Inefficiency in the Whole Model

The two partial model tests show that overtime and the sales objective adjust in a "sensible" and intuitively obvious way to an unexpected decrease in sales. In other words, there is a good rationale for why market mangers set the objectives they do and for why salesmen work the overtime they do. The final stage of the simulation analysis examines how this rationale holds up in the whole model.

Once again the model is disturbed from equilibrium by a 50% step increase in time per sale. This time all four loops are active, the two loops already examined and the two new loops (3 and 4 in Figure 4) engaged by allowing motivation to vary with overtime and performance.[13] The resulting adjustment, shown in Figure 7, is grossly inefficient. The sales organization becomes locked in a trap in which sales are well below potential, and effective sales effort falls below the standard that can be achieved with no overtime.

Why should the apparently reasonable decision rules of market managers and salesmen fail so noticeably in the more complex environment? Why is the system incapable of adjusting to the new but lowered market potential without first passing through a phase of more than two years where salesmen's productivity is well below normal?

A careful scrutiny of Figure 7 provides insight into the difficulties of managing the complete system. Monthly sales fall by 1/3 in month 4, thereby opening a large gap between sales and the objective. Salesmen put in more overtime, increasing effective sales effort and so preventing further decline in their sales performance, as shown by the leveling off of performance between months 4 and 6. So far the adjustment makes sense; however, two unforeseen problems are occurring.

First, the high level of overtime coupled with low performance causes a sharp decline in motivation. Compounding this problem, the sales objective itself does not fall as quickly as it did in isolation, because overtime is masking the decline in the market. (To illustrate this point, the figure shows superimposed the sales objective from Figure 6, when overtime was constant at 10%.) By month 10 of the simulation run, motivation has depressed sales effort below the effort available from a well-motivated force working no overtime!

Consider now the rationality of the salesmen and market managers' decisions. Salesmen, pressured by the sales objective, continue to work long hours even though their effective effort in the market falls. The result is a further decline in sales. The market managers are now very confused. They have been cautiously lowering their sales objective as they learn about the tighter market conditions. But, starting in month 9, sales begin to decline still further. The objective-setting process cannot distinguish the fall in sales caused by the market from the fall caused by lowered salesforce motivation and productivity. Cautious downward adjustment of the objective keeps the pressure on the salesmen—usually a sensible thing to do. But in the prevailing situation continued pressure *lowers* rather than raises the effective effort of salesmen. There has been a complete breakdown in the logic of the sales management and control process.

Sales continue to decline until month 20. The system is in a trap. It has been managed, or rather mismanaged, into a situation where the productivity of salesmen is much lower than normal and sales are below potential. A recovery occurs gradually after month 20, when motivation and productivity have reached rock bottom and the sales objective falls low enough to relieve the work load and performance pressure on

[13] In the model the motivation function is activated by setting the switch for motivation index *SMI* to 1 in equation (7.1) of the text. In the base model *SMI* is set to 0.

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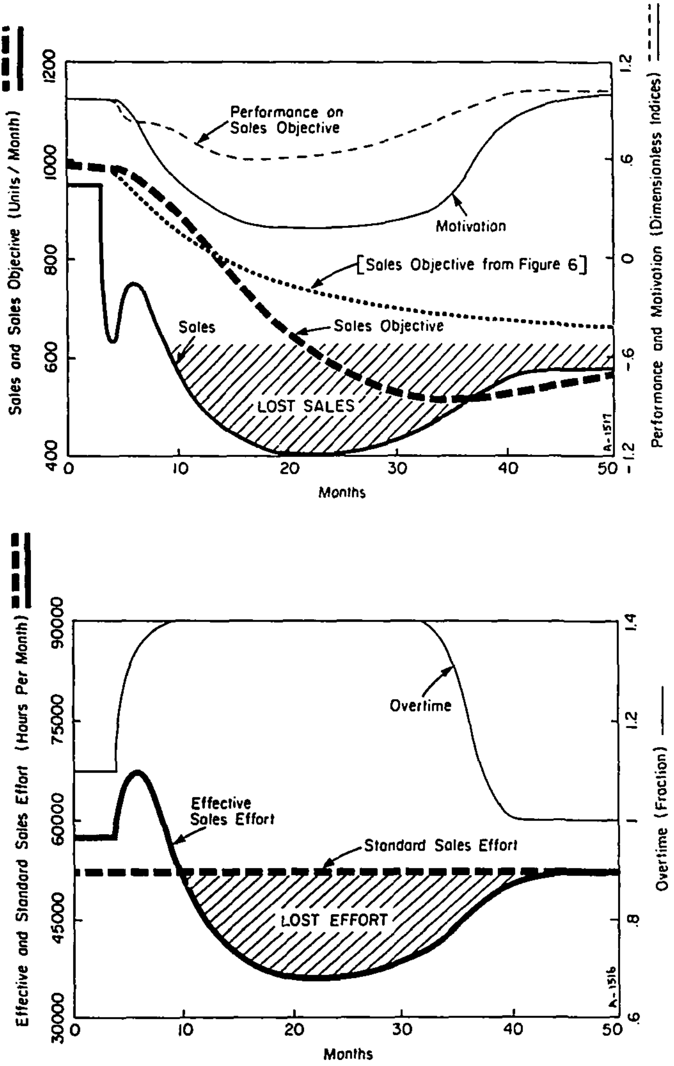

FIGURE 7. A Productivity and Sales Trap in the Full System

the salesmen. But, as the shaded areas in the figure show, there has been a substantial loss of sales and much wasted sales effort.

The feedback structure of the system, the set of four interlocking, nonlinear loops, makes sales management a hazardous task. When only moderate changes in market conditions occur, the overtime and objective-setting functions work effectively together. (A small, say, 20% increase in time per sale causes a temporary increase in overtime and a gradual relaxation of sales objectives—with no hint of a productivity or sales trap.) However, a much larger increase in time per sale activates the nonlinear motivation loops.

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When these loops become dominant, they reverse the normal response of salesmen to pressure from the sales objective. Instead of increasing their effort through overtime, salesmen work longer, but much less effectively—a result entirely in violation of the premises of the objective-setting process. Under these circumstances the market managers make dysfunctional decisions. Failing to meet their sales commitment, they (unwittingly) set objectives that guarantee a still larger discrepancy between future sales and commitment. Their decisionmaking, though intendedly rational, is not sufficiently farsighted to compensate for the large declines in sales-force productivity caused by the highly nonlinear motivation loops acting in concert.

Summary and Conclusions

The previous sections have shown how a description of the premises of decisionmaking followed by partial model tests can aid the interpretation of a system dynamics behavioral simulation model. But what do these methods of analysis provide that normal methods of equation description and simulation analysis cannot?

Clarifying the Theory Implicit in a Model

Normal methods of description and analysis leave a large gap in logic (and therefore in the theory) between the assumptions embodied in individual equations and their simulated behavior. Premise description and partial model tests bridge this gap.

Premise description relates the formulation of individual equations in a decision function to macro-organizational processes such as factoring, routines, traditions, and biases. For example, in the sales model there were two equations to represent objective setting. Premise description showed that routine trend extrapolation (requiring much less information than a data-rich market survey) was an important "process" assumption in the formulation of the equations. Simulation experiments then showed that inertia in trend extrapolation was a major factor in exacerbating the decline of sales following a tightening of the market, because sales objectives adjust too slowly to changing market conditions.

Partial model testing relates the premises of decisionmaking to simulated behavior. If we accept that organizational decisionmaking is intendedly rational, then we should expect partial model tests to reveal behavior that is intuitively clear and consistent with the premises of the model's decision functions. So, as we saw in the sales model, when motivation is held constant the overtime function always adjusts so that salesmen put in more effort and generate more sales when their performance is below objective—the intuitively correct response. However, in the whole model, when motivation can vary, the overtime function sometimes adjusts so that salesmen generate fewer sales when their performance is below objective, thereby worsening performance. A comparison of partial and whole model tests provides an explanation for dysfunctional or counter-intuitive behavior.[14]

Aid to Formulation and Policy Analysis

The understanding acquired from premise description and partial model testing can be helpful in justifying model formulations and selecting between alternative formulations. For example, awareness of the inertia (and its consequences) in the objective-setting function naturally prompts the question of why a more "intelligent" function is not in use. Why don't market managers learn more quickly about tightening market conditions and integrate them into sales objectives? One answer is that perhaps they do

[14] For another example of how partial model tests lead to a clarification of model theory, see Sterman's explanation (1985) of the causes of the Kondratieff long-wave economic cycle.

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learn quickly, but the process has not been adequately modeled. Another answer is that the information required to improve rationality (such as an accurate knowledge of salesforce motivation) is simply not available. Yet another is that the information is available but ignored. Fear of renegotiating a sales commitment may block real knowledge about changing market conditions. In any case, the modeler is prompted to scrutinize his basic assumptions.

Premise description and partial model testing are helpful in policy design. An understanding of the conditions that cause a breakdown in the rationality of a given decision function and a subsequent problem in the system may well point to the changes necessary to remedy the problem. For example, in the sales model a policy change that assumes market managers know *and act* on motivation information greatly reduces the likelihood of being caught in the productivity and sales trap. Alternatively, a policy change that assumes market managers have up-to-date and detailed knowledge of market conditions, *and* use the knowledge to renegotiate their sales commitment, avoids the trap.

In conclusion, premise description and partial model testing are useful diagnostic methods for simulation modeling. They can improve the quality of model formulation and analysis and help clarify the theory implicit in the model to both academic and managerial audiences.[15]

[15] An earlier draft of this paper was presented at the 1983 International System Dynamics Conference, Chestnut Hill, Massachusetts, July 27–30, 1983.

The author received valuable suggestions on earlier drafts of this paper from Jay W. Forrester, George P. Richardson, John M. Richardson, John D. Sterman, Robert L. Eberlein, and anonymous referees.

Funds for the preparation of this paper were provided in part by the System Dynamics Corporate Research Program of the Sloan School of Management, MIT.

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